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Importance of cattle biodiversity and its influence on the nutrient composition of beef



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Implications

- Livestock make a substantial contribution to achieving food and nutrition security due to various factors including the high nutritional quality of animal-source foods.
- Conservation and sustainable use of cattle genetic resources are important due to the multiple benefits provided by local breeds. These benefits include multiple direct uses, additional market value provided by specialty products, social and cultural roles, and adaptations that local breeds have to climate and diseases in harsh environments.
- Meat composition varies across cattle breeds. Whereas genetics play a role in this variation, management practices, such as diet, and other environmental factors also affect nutrient composition.
- Compositional data for cattle breeds have been added to the FAO/INFOODS Food Composition Database for Biodiversity. The database is publicly available and has value for use by researchers, nutritionists, producers, the general public and other stakeholders.
- More compositional data, including amino acids, minerals, and vitamins, are needed from local breeds in order to understand better the nutritional benefits of sustainably managing animal genetic resources.

Key words: animal source foods, cattle, food security, genetic conservation, genetic diversity, local breeds, meat composition, nutrition security

Introduction

Addressing food and nutrition security is and will continue to be an immense challenge. The productivity and efficiency of food systems must be improved to meet the demands of a growing population in a changing climate, but the quality of food must be able to fulfill dietary needs.

Livestock have proven to be a source of food security and nutritional quality, while providing both market and non-market benefits. Biodiversity of livestock is the foundation of the role of livestock in providing many of these benefits.

Livestock provide numerous benefits in addition to food production. Livestock provide 13 percent of global caloric consumption and 28 percent of protein consumption (FAO, 2011). In many communities, the additional non-food benefits of livestock may be even more important (Figure 1). Thanks to their ability to graze on a wide variety of plants, livestock can be raised in areas that are unsuitable for crop production. Many places where cultivation is possible are nonetheless subject to extreme environmental events that can severely damage crops and upset routine livelihoods. Livestock can also provide emergency cash in cases of crop failure or unforeseen health expenses (Freeman et al., 2007). Other practical direct uses of livestock include production of fiber from animal



Figure 1. Livestock include many benefits, including but not limited to those shown above.

hair, hides and pelts, and assistance with crop production through draft power. The value of livestock extends to environmental services such as nature management. Ruminants are able to digest plant residue from grain production. Properly-managed grazing maintains open landscapes, thus reducing the risk of fire and/or increasing wildlife biodiversity (Gregory et al., 2010). Livestock ownership has numerous socio-cultural values and is often seen as a sign of wealth in rural communities. Further, women's social status and gender equity is improved when women are allowed to own and manage livestock (Walters-Beyer and Letty, 2010).

The multifunctionality of livestock is an essential component to agriculture and achieving income security in the developing world. However, the diversity of the genetic base used for livestock production is threatened (FAO, 2007). Human population growth will pressure production needs and livestock performance. These pressures tend to favor high output breeds (Hoffman, 2010). There is a current trend of diminishing genetic diversity of livestock that are used for many functions in the developing world. Thus there is an urgent need to conserve and sustainably utilize local breeds, many of which are at risk of extinction. The purpose of this paper is to use the example of cattle to demonstrate the critical need to properly conserve biodiversity by demonstrating the benefits of local breeds of livestock and articulating the impacts genetic diversity has on nutritional composition of beef.

Contribution of Local Breeds of Cattle

The term "local breed" refers to a breed that is found in a single country or geographical area and has an impact on a small scale and local level (Hoffman, 2010). Local breeds of cattle can provide additional values (Figure 2) that are not often found in more widespread international transboundary breeds, which are specialized to produce a single output (Hoffman, 2010). These benefits can come from a variety of sources such as meat, milk, hides, manure, and transportation services. Local breeds also fulfill a variety of social and cultural uses. Livestock are used frequently as a symbol of social status, in religious ceremonies, or in recreational activities. Many of these uses have been documented in the Country Reports prepared for The State of the World's Animal Genetic Resources. Uganda's report compares three types of indigenous cattle: Ankole Longhorn, Short-horned Zebu, and Nganda. Regarding social function, Ankole and Zebu breeds stand out from other breeds because they are highly valued for use as dowries (Government of Uganda, 2004). In Indonesia, Madura cattle are renowned for their use in races as a form of recreation, and these cattle also denote high social status (Ministry of Agriculture, Republic of Indonesia, 2003). Tswana cattle are used for weddings and funerals, as dowries, and in healing ceremonies in Botswana (Masilo and Madibela, 2003).

Even when only direct use products such as meat, milk, and fiber are con-

sidered, local breeds of livestock still offer increased economic merit to the native regions where they are raised. Local breeds of livestock are the source of value-added products in the marketplace, such as specialty meats, cheeses, milk, and nonfood items (Gandini et al., 2007; FAO, 2009). These products can have additional worth because they come from particular breeds that are raised in specific locations under specialized production systems (Casabianca and Matassino, 2006; Diaferia et al., 2006; Zhou and Zhao, 2012).

Biodiversity is also a key component to addressing management concerns including parasites, diseases, and harsh environments. Conservation of local breeds will empower producers to address concerns such as ticks (Wambura et al., 1998) and trypanosomosis (Courtin et al., 2008). Finally, heat tolerance is highly valued in many regions in the world and genetic variation in this trait is documented in many different instances (Gaughan et al., 1999; Beatty et al., 2006).

Nutritional Contributions of Beef

Meat products are important contributors of nutrition to human diets, as they provide essential protein, amino acids, minerals, and vitamins (McAfee et al. 2010; De Smet, 2012). Locally produced foods in highly biodiverse areas are known to be important sources of nutrients, particularly micronutrients (reviewed by Penafiel et al., 2011). Although many contributions of cattle are documented, there has been a lack of easily accessed information about how biodiversity of cattle affect the beef that is produced in transboundary and local breeds. Because of this, there is a need to document the variation of meat composition across many breeds of livestock, including local breeds, and assess the available nutrition in different parts of the world. To address this need, compositional data on the meat of cattle breeds were added to the FAO/INFOODS Food Composition Database for Biodiversity, referred to as the FAO/INFOODS database in this document (FAO, 2012). This database aims to increase the science-based evidence on the compositional differences of food bio-

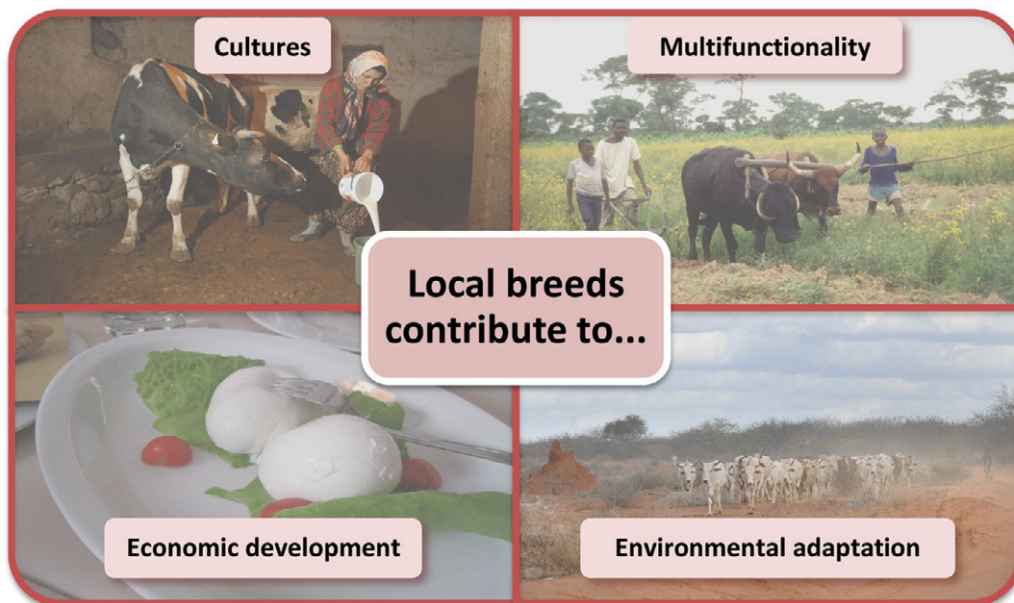


Figure 2. Local breeds of livestock contribute to human cultures by influencing gender roles, serving multiple uses for producers, allowing for the production of specialty products which promote economic development, and having environmental adaptations that allow them to perform under harsh environmental conditions (source: FAO).

Table 1. Variation of nutrient values among different breeds in raw *Longissimus* muscle. Data are from the FAO/INFOODS database and are presented per 100 g edible portion (EP) on fresh weight basis.

Component	Range in database	Mean \pm standard deviations in database	Breed with least content in database	Breed with greatest content in database	USDA Beef Ribeye, trimmed of all fat, raw ^a
Moisture, g	62.6-77.7	73.4 \pm 3.1 n = 64	Hanwoo ⁱ (South Korea)	Bonsmara ^u (South Africa)	71.6
Protein, g	18.56-25.67	21.78 \pm 1.07 n = 64	Brown Swiss ^v (Spain)	Criollo Argentino ^w (Argentina)	22.66
Fat, g	0.59-16.01	3.15 \pm 2.70 n = 123	Hereford-Friesian Cross ^x (New Zealand)	Hanwoo ⁱ (South Korea)	4.66
SFA, g	0.14-8.39	1.54 \pm 1.69 n = 63	Austriana Valles ^u (Spain)	Hanwoo ⁱ (South Korea)	1.68
MUFA, g	0.10-5.92	1.36 \pm 1.27 n = 62	Austriana Valles ^y (Spain)	Hanwoo ⁱ (South Korea)	2.16
PUFA, g	0.08-1.46	0.26 \pm 0.23 n = 58	Criollo Argentino ^w (Argentina)	Charolais x Angus ⁱ (Argentina)	0.19
C14:0, g	0.009-0.601	0.084 \pm 0.010 n = 86	Austriana Valles ^z (Spain)	Hanwoo ⁱ (South Korea)	0.115

n = number of individual data points; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids

^aUSDA, 2011, ⁱPango et al. 2010. ^uMuchenje et al. 2009. ^vVieria et al. 2006. ^wOrellana et al. 2009. ^xPurchas et al. 1997. ^yInsausti et al. 2004. ^zGarcia et al. 2008.

(source: <http://ndb.nal.usda.gov/ndb/foods/list>)

diversity. It will allow users to easily assess compositional data on local varieties, cultivars, and breeds as well as wild and underutilized species (Toledo and Burlingame, 2006; FAO, 2008).

To compose the beef section of the FAO/INFOODS database, a multi-step process was used. An extensive literature search was conducted using the following keywords: beef, biodiversity, breeds, developing countries, human nutrition, lipid content, lipid profile, local breed, meat composition, micro-nutrients, minor breed, nutrient composition, and protein profile. Composition data were extracted from these peer-reviewed articles. In many cases, conversions were required to make a consistent presentation of each component based on per 100 g edible portion on a fresh weight basis (EP). Composition data from 39 papers, representing 49 breeds, resulted in 213 food entries into the FAO/INFOODS database. Angus (n = 20), Belgian Blue (n = 14), Hereford (n = 14), Barossa (n = 12), Braford (n = 7), Simmental (n = 5), and Limousin (n = 5) represented the greatest number of records. The remaining records include other purebreds or specifically identified crossbred cattle. The following components are included in the database: water (64 records), protein (64 records), fat (145 records), total monounsaturated fatty acids (75 records), total polyunsaturated fatty acids (71 records), total saturated fatty acids (67 records), individual fatty acids (110 records), minerals (26 records), and vitamins (12 records). Data for the *Longissimus dorsi* were reported in 166 records.

The accuracy of the entries was monitored by a series of quality control checks including 1) the sum of proximate (weight in grams) [water + protein + fat + ash] is within the range of 105–105 g; 2) the value for total fatty acids, or any individual fatty acid is lower than the value for total fat; and 3) the ash value is higher than the sum of single minerals.

A summary of the data entries for raw *Longissimus dorsi* compiled in the FAO/INFOODS database is outlined in Table 1. The values presented in the table show substantial variations in particular for fat and fatty acid values. These differences can partially be explained by the diversity of genotypes represented. However, other animal management practices

(e.g., diet, age of slaughter) can have a large impact on the composition of the meat. The FAO/INFOODS database is unique from other general databases, because animal genetics as well as other information such as production practices are recognized and documented and can be taken into account for further analyses. For comparison, the means for Beef Ribeye across grades, taken from the USDA National Nutrient Database for Standard Reference (USDA, 2011) are presented in Table 1. In general, the data from the USDA Database are consistent with the means summarized from the FAO/INFOODS database. It is noteworthy that there is a great deal of variation in the means from the FAO/INFOODS database, possibly signaling the effect of greater breed diversity and management practices represented in the FAO/INFOODS database. For example, the Hanwoo beef breed of South Korea has been selected and managed to produce beef that has a great proportion of intramuscular lipid (Jo et al., 2012). Therefore, it is not surprising that the meat from this breed had the greatest fat content.

Demonstration of Biodiversity

The need for conservation of genetic resources and the value of biodiversity of cattle to multifunctionality are understood (Hoffman, 2010). In many cases, what is not known is what the contribution of biodiversity is to variation in nutrient content. A significant advantage of the FAO/INFOODS database is that it documents the relative contribution of genetics to the nutrient composition of food. To demonstrate the differences in meat composition across contrasting breeds and species of cattle, several key papers were selected from the FAO/INFOODS database for further analysis.

Xie et al. (2012) analyzed meat from local breeds of the region and compared it to meat from breeds that have undergone specific selection programs. All cattle in the study were of similar age and fed the same diet to decrease the chance of confounding effects. Composition of the *Longis-*

Table 2. Comparison of proximate and fatty acid composition in raw *Longissimus dorsi* of five Chinese breeds. Data are presented per 100 g edible portion (EP) on fresh weight basis.

	Limousin (commercial breed)	Simmental (commercial breed)	Luxi (local breed)	Qinchuan (local breed)	Jinnan (local breed)
Moisture, g	75.8	74.6	74.5	74.7	74.4
Protein, g	21.46	21.73	21.46	22.09	21.6
Fat, g	2.00	2.59	2.78	2.65	2.64
Ash, g	0.89	1.03	1.24	0.80	1.31
SFA, g	0.93	1.01	0.93	0.91	0.90
MUFA, g	0.81	0.92	0.78	0.68	0.76
PUFA, g	0.12	0.13	0.14	0.18	0.13
C14:0, g	0.064	0.061	0.053	0.043	0.049
C16:0, g	0.520	0.561	0.491	0.461	0.496
PUFA <i>n</i> -3, g	0.012	0.010	0.008	0.020	0.008

All components presented were re-calculated to represent amount per 100 g EP on fresh weight. Statistical comparisons are therefore not shown.

SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids

(source: Xie et al., 2012)

simus dorsi (Top Loin) of each carcass was determined (Table 2). Some of the most prominent differences between these breeds can be seen by comparing myristic acid (C14:0), monounsaturated fatty acids (MUFA), and protein data. Myristic acid is a saturated fatty acid that has been shown to increase levels of low-density lipoproteins (LDL) and decrease levels of high-density lipoproteins (HDL). Increased concentrations of LDL can have a detrimental effect on human health, as it increases the risk of coronary artery disease (Mensink et al., 2003). In this study, the local breeds Qinchuan, Luxi, and Jinnan produced beef that contained lesser proportions of myristic acid compared to the commercial breeds Limousin and Simmental. In contrast, beef from the commercial breeds contained more MUFA than the local breeds. Replacement of saturated fatty acids with cis-MUFA can decrease the LDL:HDL ratio and perhaps reduce the risk of coronary artery disease (Kromhout et al., 2012).

Genetic variability in meat composition cannot be summarized as a simple difference between local and international transboundary breeds. Significant differences have been reported in the protein composition of meat samples from different local breeds. Raw meat from the *Longissimus dorsi* of Limousin and Qinchuan cattle did not differ significantly in protein content despite the fact that one is a commercial breed and one is a local breed. Comparing the protein content of the Jinnan, which is greater than the Qinchuan breed, is an example that demonstrates the variability in data among local breeds (Xie et al., 2012). Protein is important when discussing human nutrition as it not only provides calories, but essential amino acids that assist in building and preserving body muscle and tissues (DGAC, 2010). Amino acids are an important aid in the prevention of sarcopenia, osteoporosis/osteopenia, cardio-

vascular disease, and Type II diabetes. Beef and other animal source foods contain high-quality proteins that are highly digestible, making them especially appealing as a contributor to human nutrition (McNeill and Monroe, 2008; McNeill and Van Elswyk, 2012).

Indurain et al. (2010) documented substantial differences among seven Spanish breeds in fat and fatty acids content for animals fed the same diet. A summary of these values is presented in Table 3. Beef from Asturiana cattle contained significantly less fat when compared with the other breeds. Meat from Asturiana cattle also had the least myristic acid whereas the meat from the Morucha breed contained the most myristic acid.

Differences also exist across local breeds, commercial breeds, and their crosses (Barton et al., 2010; Table 4). Beef from Czech Fleckvieh, a local breed, contained more protein and tended to have a greater fat content than beef from the Charolais fed a the same diet. The contribution of genetics to composition is evident in this example as the *Longissimus dorsi* from the crossbred cattle was intermediate to the two purebred experimental groups.

Just as genetics play an important role in the diversity of nutritional composition, animal management practices also contribute to nutritional differences. A study performed in Wales (Warren et al., 2008) demonstrates the role of management practices by comparing Aberdeen Angus

Table 3. Comparison of fat and fatty acids in raw *Longissimus dorsi* of seven Spanish breeds. Data are presented per 100 g edible portion (EP) on fresh weight basis.

	Asturiana	Avilena	Morucha	Parda Alphone	Pirenaica	Retinta	Rubia Gallega
Fat, g	1.06 ^a	3.21 ^{bc}	3.10 ^c	2.66 ^{abc}	2.32 ^{ab}	2.42 ^{abc}	2.10 ^a
C14:0, g	0.024	0.067	0.076	0.058	0.055	0.060	0.059
PUFA <i>n</i> -3, g	0.009	0.014	0.011	0.014	0.012	0.012	0.018

^{a-c} Means in the same row with different superscripts are significantly different.

^d MSE of fat content = 0.3 g/100 g EP

Fatty acid data presented were re-calculated to represent amount per 100 g edible portion on fresh weight basis. Statistical comparisons are therefore not shown.

PUFA *n*-3 = total of C18:3 *n*-3 and C22:6 *n*3

(source: Indurain et al., 2010)

Table 4. Comparison of selected components in raw *Longissimus lumborum* of three Czech breeds. Data are presented per 100 g edible portion (EP) on fresh weight basis.

	Czech Fleckvieh	Charolais X Czech Fleckvieh	Charolais
Moisture, g	75.5 ^a	75.7 ^a	76.4 ^b
Protein, g	21.18 ^a	21.02 ^{ab}	20.62 ^b
Fat, g	1.40	1.28	1.08
SFA, g	0.62	0.58	0.50
MUFA, g	0.52	0.46	0.36
PUFA, g	0.10	0.10	0.09
C14:0, g	0.028	0.029	0.023
C16:0, g	0.347	0.323	0.270

^{a,b} Means in the same row with different superscripts are significantly different.

Protein SEM= 0.15, Moisture SEM = 0.17

Fatty acid data presented are re-calculated to represent amount per 100g edible portion. Statistical comparisons are therefore not shown.

SFA = C14:0 + C16:0 + C18:0

MUFA = C14:1n-5 + C16:1n-7, + C18:1n-9 + C18:1n-7 + C18:1n-11t

PUFA = C18:2n-6 + C20:3n-6 + C20:4n-6 + C22:4n-6 + C18:3n-3 + C20:5n-3 + C22:6n-3

(source: Barton et al. 2010)

cattle and Holstein-Friesian cattle being fed two different diets consisting of concentrate (barley, molassed sugarbeet pump, molasses, and full-fat soya) and silage. Analyses were conducted on raw samples of the *Longissimus dorsi* (Table 5). The results indicate considerable differences in fat between the breeds in response to diet. It is particularly important to observe the significantly greater fat content in the Aberdeen Angus *Longissimus dorsi* due to silage feeding. This difference in fat content is also apparent in meat from the Holstein-Friesian cattle, which contained substantially less fat when the cattle were fed concentrate compared to silage. The results do show that breeds may respond differently to management practices. This is consistent with other examples (reviewed by Scollan et al., 2006). The results of this study demonstrate the value of a database that provides detailed information about the relation between nutrient values, genetics, and animal husbandry. In the future, questions regarding the relative importance of breeds and management practices can be addressed using the FAO/INFOODS database section for meat.

Conclusion

Livestock provide a wide range of socio-economic, environmental, and nutritional benefits and have a great amount of genetic diversity. From this genetic diversity, highly productive international transboundary

commercial breeds have been developed, whereas many local breeds still fit particular niches. Although increased use of transboundary breeds has been promoted as a solution to food and nutrition insecurity, it is critical to understand that while production is important, other factors such as multiple uses of local breeds, ecological services, and social customs must be taken into consideration when developing breeding programs. Local breeds of livestock, particularly cattle, have many values around the world.

Genetic diversity also leads to differences in nutritional composition of meat. Scientific evaluation is needed for the comparison of breeds because no simple conclusions can be drawn between the nutritional values of broadly-classified commercial and local breeds. Breed diversity and management practices affect nutrient composition of meat. To document these differences, current literature has been used to populate the FAO/INFOODS database with beef composition data. Using the database, it is possible to quantify differences across breeds and to demonstrate genetic diversity among cattle. The information from this database connects both nutrition and biodiversity.

Current records in the meat section of the database have an emphasis on cattle breeds from developed countries. Although these data are important and useful for demonstrating genetic differences among breeds and how it affects nutritional composition, more records from a wider range of

Table 5. Comparison of fat and fatty acid composition in raw *Longissimus* muscle of Aberdeen Angus and Holstein Friesian fed different diets. Data are presented per 100 g edible portion (EP) on fresh weight basis.

	Aberdeen Angus		Holstein-Friesian	
	Fed concentrate	Silage	Fed concentrate	Silage
Fat, g	3.13 ^a	6.17 ^b	2.84 ^a	3.67 ^a
MUFA, g	1.24	2.68	1.13	1.63
PUFA <i>n</i> -3, g	0.02	0.11	0.02	0.10

^{a,b} Means in the same row with different superscripts are significantly different. Fatty acid data presented were re-calculated to represent amount per 100 g EP. Statistical comparisons are therefore not shown.

MUFA = (C16:1 + C18:1c-9 + C18:1c-11 + C18:1t-11 + C20:1).

PUFA *n*-3 = (C18:3n-3 + C20:4n-3 + C20:5n-3 + C22:5n-3 + C22:6n-3).

(source: Warren et al., 2008)

breeds will improve the usefulness of the database, particularly scientific records from local breeds in developing countries. Additional information gaps in the database include, but are not limited to, the contents of amino acids, minerals, and vitamins. Further information about a greater variety and muscles and cuts of meat is also required.

Improved management of livestock biodiversity needs to become a priority for researchers, development organizations, and policymakers if the role of livestock will continue to be an essential component to achieving food and nutrition security. Continued loss of livestock genetic resources will only compound the challenges of food and nutrition security around the world. Having greater understanding of the variation in nutrient content among different breeds (including local breeds) will allow researchers, nutritionists, development workers, citizens, and policy makers to understand and work through the complexity of food insecurity. Recognizing this intricate challenge, better development approaches can emerge and food security can be improved for the future.

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About the Authors



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Paul Boettcher is an animal production officer at the FAO in Rome, Italy. The primary activity of his work is to assist countries to implement the Global Plan of Action for Animal Genetic Resources, with a particular emphasis on conservation and on application of biotechnologies. Boettcher was raised on a dairy farm in Wisconsin and holds a B.S. from the University of Wisconsin, M.S. from the University of Minnesota and Ph.D. from Iowa State University. Boettcher has previously worked as a research scientist in Canada and Italy and at the IAEA-FAO Joint Division in Vienna, Austria.

Ruth Charrondiere holds a Ph.D. in nutrition and has mainly worked at UN agencies (WHO, UNICEF and currently at FAO) in several fields: nutritional assessment (Ethiopia), food consumption surveys, and instruments within the EPIC project (European Prospective Investigation into Cancer and Nutrition). Dr. Charrondiere is the coordinator of INFOODS (International Network of Food Data Systems).

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Barbara Stadlmayr is a nutrition scientist working as a consultant at FAO-headquarters. She has been working in the area of food composition for three years. During this time, she worked on several publications including the West African Food Composition Table and the FAO/INFOODS Food Composition Database for Biodiversity. She assisted in food composition trainings and she is author and co-author of several scientific articles.

Authors Kimberly Barnes, Trisha Collins, Sandra Dion, Heidi Reynolds, Samantha Riess, Andrew Stanzyk, and Anna Wolfe are Iowa State University students enrolled in the Dean's Global Agriculture and Food Leadership Program. This integrated production and policy program is designed enhance student learning with respect to global agricultural production, resources, and food issues. This team of students worked with project mentors at FAO (Paul Boettcher, Ruth Charrondiere, and Barbara Stadlmayr) to add beef composition to the FAO/INFOODS Food Composition database for Biodiversity. Until the student team took on this job, no data for meat was available in the database.